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ALTITUDE DETERMINATION USING A BINOCULAR VIEWER

by Jacob H. Lichtenstein and William T. Suit

Langley Research Center
Langley Station, Hampton, Va.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • NOVEMBER 1969

1. Report No. NASA TM X-1926	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle ALTITUDE DETERMINATION USING A BINOCULAR VIEWER		5. Report Date November 1969
		6. Performing Organization Code
7. Author(s) Jacob H. Lichtenstein and William T. Suit		8. Performing Organization Report No. L-6746
9. Performing Organization Name and Address NASA Langley Research Center Hampton, Va. 23365		10. Work Unit No. 127-51-17-09-23
		11. Contract or Grant No.
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration Washington, D.C. 20546		13. Type of Report and Period Covered Technical Memorandum
		14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

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17. Key Words Suggested by Author(s) Navigation Binocular viewer Altitude measuring device	18. Distribution Statement Unclassified – Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclassified	Unclassified	21	$3.00

*For sale by the Clearinghouse for Federal Scientific and Technical Information
Springfield, Virginia 22151

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SUMMARY

An evaluation of an optical viewing device, called a binocular viewer, and its aid to an observer in estimating his altitude above a spherical surface with a radius of 1080 miles (1737.7 km) was made. The observer used the method of matching the horizon curvature, as seen through the viewer, with previously calibrated arcs that also appear in the viewer to indicate the altitude. Twenty-three subjects were used and the simulated altitudes varied from 0 to 115 miles (0 to 185 km).

The results showed that the formation of the optical surfaces was very critical and that minor errors in the surface could appreciably affect the estimated altitude. In addition, it was found that the observers could estimate their altitude to within ±5 miles (±8 km), and that whether or not the observer needed corrective lenses had no appreciable effect on the results.

INTRODUCTION

The role that man will play in future space flights is dependent upon his ability to perform those tasks necessary for the successful accomplishment of the mission. Considerable effort has been expended in attempting to evaluate how well man can perform the tasks of navigation and guidance. (See refs. 1 to 4, for example.) Among the tasks being evaluated is the measurement of the orbital parameters by the pilot. The altitude of the spacecraft above the surface of a planetary body is an important parameter, but is difficult to measure by visual means. An investigation to measure man's ability to determine his altitude by simple visual means is reported in reference 5. In that investigation, the observer tried to match previously calibrated arcs scribed on a template to the horizon curvature that was displayed before him. However, the restrictions on the equipment, such as a relatively narrow field of view (about 40^{o}) limited the performance of the test subjects, and the altitude determination, therefore, was very poor.

The Manned Space Craft Center, appreciating the potential of pilotage for spaceflight, contracted with Geonautics Inc. (contract No. NAS9-3006) to study methods of pilotage for spacecraft. The contractor was to define direct-view optical instruments, and other aids required for spacecraft pilotage. The main development of this contract was the design

and construction of optical devices which were called "binocular viewers." Three viewers were contracted; however, only two were sent to the Langley Research Center for evaluation. These viewers used scribed reseaux (specialized forms of reticles) of various patterns to measure the orbit parameters. For altitude measurement a horizon-arc-matching method was used similar to that discussed in reference 5. However, the binocular viewer is a more sophisticated device which had a much wider field of view (about 90°). This wider field of view would be expected to improve the test subject's ability to make measurements.

The binocular viewer could become a useful backup aid for determining orbital parameters, if its use would result in orbit parameters of acceptable accuracy. The accuracy required for a particular mission depends on that individual mission and therefore no attempt to define these limits will be made. An evaluation of these viewers therefore was undertaken; and in this paper the results of altitude determination tests are presented that were made with 23 untrained subjects using the binocular viewer with the horizon-arc-matching method and with arcs representing altitudes from 0 to 115 miles (0 to 185 km).

APPARATUS AND METHODS

Viewer

The basic apparatus used in the tests was the "binocular viewer." The viewer is a relatively light, compact, self-contained unit which is about 12 inches (304.8 mm) wide, 9 inches (228.6 mm) high, and 8 inches (203.2 mm) deep. Photographs showing essentially the side and rear views are presented in figure 1, and a pictorial sketch of this binocular viewer in use is shown in figure 2. The viewer dimensions were dictated by the fact that a horizontal field of view of 90° was required. The inner edge of the binocular viewer is formed to fit flush with the helmet of the astronaut.

In order for the viewer to accommodate both eyes of the observer exactly, it is necessary that the optical surfaces be aspheric. During design of the instrument, however, it was found that this deviation from spherical was so small that it was within the manufacturing tolerances; consequently, the correction was omitted and the surfaces were made spherical. Thus, the optics consist of two concentric spherical sections in which the front or outer section has a 7-inch (177.8 mm) radius and the rear one has a 3.5-inch (88.9 mm) radius. The outer section is half silvered so that light from outside passes through, but part of the light striking the inside is reflected. The inner section which is called a reseau is clear and has line patterns scribed on it. The actual scribed lines can be seen in the rear-view photograph in figure 1. The line patterns for the altitude determination test as they appear to the observer projected on the screen are shown in figure 2.

The spacing between the lines is logarithmic for even increments in altitude, the lines becoming closer together as the altitude increases. These lines are illuminated by small bulbs at the edges of the reseau.

The light emanating from any point on the reseau is reflected off the inside surface of the outer section back toward the observer in such a manner that all the reflected rays travel in parallel paths. Therefore, to an observer looking through the viewer, the lines on the reseau are apparently at infinity and appear to be superimposed on the scene observed through the viewer.

Test Setup

The test setup is shown in figure 3. The binocular viewer and a head retainer were attached to a common base and then mounted on a tripod. The head retainer consisted of a chin rest and a forehead rest. Both of these rests were adjustable so that the observer's eye could be located approximately in a plane containing the center of curvature of the two concentric spherical sections of the viewer.

The display for the observer is provided by a 35-mm slide projector. A total of 41 slides, which simulated altitudes ranging from 0 to 115 statute miles (0 to 185 km), were used and they were made so that a smooth horizon was presented to the observer. These slides were made to represent altitudes above a spherical surface with a radius of 1080 statute miles (1737.7 km). The altitude increment between slides was either 2 or 3 miles (3.2 or 4.8 km) so that every 5th and 10th mile (8th and 16th km) was presented (that is, 0, 2, 5, 8, 10, etc.). The curvatures of the various slides were computed to represent the horizon curve that an observer would see if he was at a given altitude and had a 90° field of view.

In order to provide a 90° field of view to the observer, a display screen 10 feet (3.048 meters) wide was used. The observer therefore was placed 5 feet (1.524 meters) from the screen. The projector that was used had a 40° projection angle lens and in order for the image to fill the 10-foot (3.048-meter) screen, it was necessary to set the projector about 25 feet (7.62 meters) from the screen. The equations used for the computation of the radius of curvature of the slides are presented in the appendix of reference 5.

The tripod that the viewer and head retainer were mounted on had three rotational degrees of freedom and one of elevation. The elevation adjustment was used to place the observer's head at as comfortable a position as was possible. By using the rotational adjustability of the tripod, the observer was able to orient the viewer so that the horizontal line of the reseau (the line of zero altitude) was tangent to the displayed horizon and the falloff of the projected horizon was equal on each side of the center of the reseau.

The observer could then compare the displayed horizon curvature with the curvature of the calibrated reseau lines which were optically superimposed on the display. In this way the observers estimated their simulated altitude.

Tests

Two prototype optical viewers, labeled 1 and 2, were received for evaluation. Each had its own set of reseaux. The first tests were made to compare the two viewers. For these tests 4 observers and 10 slides were used in which the altitude increment between slides was 10 statute miles (16 km) (for 10 to 110 statute miles (16 to 176 km)). Then a more thorough evaluation, using one of the viewers, was made in which 23 observers and all 41 slides were utilized. The slides were presented in an arbitrary order so that the observers would get no indication of the altitude being presented from slides previously presented.

The test subjects were engineers and mathematicians that were readily available. In order to determine whether the necessity for wearing corrective lenses would affect the ability of the observer to use the viewer, the 23 observers were selected so that they fell into 3 groups. The groups consisted of 10 observers who normally wore no glasses, 10 observers who wore glasses, and 3 observers who wore contact lenses. The subjects were tested for both near and far visual acuity using a Bausch & Lomb orthorator eye tester. Twenty-two subjects were tested. One subject was not available at the time eye tests were made. A rating of 20/22.5 is considered to be satisfactory for most visual tasks. The near- and far-acuity scores were compatible except for two subjects. Only two subjects had either near or far visual acuity scores that were worse than 20/22.5. Seven subjects had acuity scores of 20/22.5 for either near or far vision, and 13 had scores of 20/20 or better. The results of a comparison of the subject's visual acuity and his performance using the binocular viewer showed that there was no correlation between his ability to estimate altitude and his visual acuity.

Since the observers were only 5 feet (1.524 meters) from the screen and the projected reseau lines appear at infinity, it was recognized that an accommodation problem may be present (inability of the observer to focus accurately enough on both displays simultaneously). In order to investigate this effect, some tests were made in which the observer was placed 11 feet 10 inches (3.6 meters) from the screen and the projector correspondingly farther from the screen. The slide projector was placed as far from the screen as possible and the resulting image size dictated the observation distance. It was believed that if there was any effect, it would manifest itself most noticeably by improvement in the large errors rather than in the small ones. Therefore, the subjects picked for these tests were, in general, those who had large errors in the regular tests.

RESULTS AND DISCUSSION

Comparison Tests

The two binocular viewers which were sent to Langley Research Center for evaluation were supposedly identical in construction. However, some preliminary tests conducted with the two viewers showed that considerably different readings were obtained for the same test conditions (that is, observers and slides). The results of these tests are shown in table I.

TABLE I.- COMPARISON OF RESULTS FOR VARIOUS VIEWER AND RESEAU COMBINATIONS

[Results are for four observers with various types of eyeball refractive conditions]

(a) Values in miles

Actual altitude, miles	Binocular viewer 1; reseau 1		Binocular viewer 2; reseau 2		Binocular viewer 1; reseau 2		Binocular viewer 2; reseau 1	
	A	B	C	D	E	F	G	H
	Average of readings	Error, miles	Error, miles	Average of readings	Average of readings	Error, miles	Error, miles	Average of readings
10	22.0	12.0	0	10.0	23.3	13.3	0	10.0
20	36.25	16.25	-0.5	19.5	35.0	15.0	-1.25	18.75
30	45.0	15.0	2	32.0	40.0	10.0	0	30.0
40	54.0	14.0	0	40.0	50.0	10.0	0	40.0
50	72.5	22.5	4.2	54.17	67.5	17.5	-2.50	47.5
60	76.0	16.0	0	60.0	78.3	18.3	0	60.0
70	87.5	17.5	2.5	72.5	85.0	15.0	2.50	72.5
80	100.0	20.0	-1.25	78.75	97.5	17.5	-2.50	77.5
90	106.67	16.7	-3.75	86.25	103.3	13.3	0	90.0
100	120.0	20.0	0	100.0	116.7	16.7	-5.0	95.0
110	115.0	5.0	7.5	117.5	118.75	8.75	-5.0	105.0
Average		15.9	0.97	. . . .	. . . .	14.12	-1.25	
Standard deviation, σ . .		5.85	3.17	. . . .	. . . .	3.99	4.59	

(b) Values in kilometers

Actual altitude, km	Binocular viewer 1; reseau 1		Binocular viewer 2; reseau 2		Binocular viewer 1; reseau 2		Binocular viewer 2; reseau 1	
	A	B	C	D	E	F	G	H
	Average of readings	Error, km	Error, km	Average of readings	Average of readings	Error, km	Error, km	Average of readings
16.09	35.41	19.31	0	16.09	37.50	21.40	0	16.09
32.19	58.34	26.15	-.80	31.38	56.33	24.14	-2.01	30.18
48.28	72.42	24.14	3.22	51.50	64.37	16.09	0	48.28
64.37	86.90	22.53	0	64.37	80.47	16.09	0	64.37
80.46	116.68	36.21	6.76	87.18	108.63	28.16	-4.02	76.44
96.56	122.31	25.75	0	96.56	126.01	29.45	0	96.56
112.65	140.82	28.16	4.02	116.68	136.79	24.14	4.02	116.68
128.75	160.93	32.19	-2.01	126.74	156.91	28.16	-4.02	124.72
144.84	171.67	26.88	-6.04	138.87	166.25	21.40	0	144.84
160.93	193.12	32.19	0	160.93	187.81	26.88	-8.05	152.89
177.03	185.07	8.05	12.07	189.10	191.11	14.08	-8.05	168.98
Average		25.59	1.56	. . . .	. . . .	22.72	-2.01	
Standard deviation, σ . .		9.41	5.10	. . . .	. . . .	6.42	7.39	

The average error and standard deviation are defined as (see ref. 6, for instance)

$$\text{Average error} = \frac{\sum_{i=1}^{N} \Delta X}{N}$$

and

$$\text{Standard deviation} \quad \sigma = \sqrt{\frac{\sum_{i=1}^{N} (X_i - \overline{X})^2}{N}}$$

where

X	altitude reading
$\overline{X}$	average reading, $\frac{\sum_{i=1}^{N} X_i}{N}$
ΔX	difference between reading and slide altitude
N	total number of readings

The data presented in table I for each of the altitudes is an average of the readings obtained from the four observers taking part in this test. The viewers were tested as they came, that is viewer 1 with reseau 1, and viewer 2 with reseau 2. The results of these tests are shown in columns A to D. A comparison of the data shows that the results obtained by using viewer 2 were much better than those obtained with viewer 1 as can be seen by comparing the summations under columns B and C. It was realized that this difference in results could be due to inaccuracies in forming either the front mirror or the reseau. Therefore, some tests were made in which the reseaux were interchanged in the viewers, reseau 1 in viewer 2, and reseau 2 in viewer 1. The results of these tests are shown in columns E to H. These results are very similar to those for the original combinations; viewer 2 was still much better than viewer 1. These results can be seen by comparing the summations under columns F and G. These tests showed that the front mirror of viewer 1 was probably improperly formed and thus responsible for the large

errors. As a result of this condition, it was decided to use only the "good" viewer (viewer 2, reseau 2) for the more extensive evaluation tests.

Evaluation Tests

The so-called "good" viewer also had some distortion out near the edges of the reseau and therefore introduced errors if the comparisons between the reseau curves and the projected horizon were carried too close to the ends of the reseau curves. The numbers used for identifying the various curves fortunately were located at the outer part of the reseau curves where the comparison of the curves began to be questionable. The subjects were instructed not to consider the parts of the reseau curves beyond these numbers; thus, the effective field of view of the viewer for good comparison was reduced from the nominal 90° to 75°. However, because exclusion of part of the curve in this manner is a subjective process, there is no actual measure of how much this process influenced the observer.

The data shown in figure 4 is a compilation of all the readings for all the observers. A number adjacent to a symbol shows the number of times that estimation was made. The data show that, in general, the 1:1 correlation of the estimated readings with the presented altitudes was fairly good. However, as the altitude increased, the readings tended to spread farther from the correlation line.

The highest altitude curve on the binocular viewer reseau represents an altitude of 80 miles (128.7 km). In the tests, slides corresponding to altitudes up to 115 miles (185 km) were presented so as not to introduce a cut-off error bias at the higher altitudes. However, this condition meant that the observer had to extrapolate the reseau pattern from 80 miles (128.7 km) up to these higher altitudes in order to estimate the presented altitude. Therefore, it was expected that the estimation errors would be larger for these altitudes than for those below 80 miles (128.7 km) where there was a reseau curve on both sides of the presented curve. Observation of the data in figure 4 shows that for presented altitudes above 90 miles (144.8 km), there were no readings of 80 miles (128.7 km) or less; therefore, all data for slides above 90 miles (144.8 km) are omitted from the remainder of the figures and analysis.

The variation of increasing error with altitude arises mainly from two causes which are inherent in the equipment:

(1) The first and general cause is the fact that the spacing of the altitude curves on the reseau follows a logarithmic variation, as mentioned previously. The curves

at the high altitudes are much closer together than those at the low altitudes. Therefore, if the observer can locate the projected horizon curve to within, say 0.01 inch (0.254 mm) between two reseau curves, this 0.01 inch (0.254 mm) will result in a larger error at high altitudes than at low altitudes.

(2) The second is a specific cause and is a result of the manufacturer's inability to reproduce the front bubble with sufficient accuracy. A careful examination of the view seen through the viewer showed that the left side of the viewer introduced distortions so that the horizon curvature on the left side was different than that on the right. Even though the correct curvature was known, the left side could not be matched well. Although this distortion was discernible at low altitudes, it did not have much effect until the simulated altitude became greater than 40 miles (64.36 km). In addition, on both sides of the reseau curves, the outer portion (about one-fifth) had some distortion which introduced errors if the full reseau was used. The errors obtained from these distortions were accentuated by the effect of reason (1).

The relationship between the magnitude of the average error and the standard deviation is shown in figure 5. This figure also presents the magnitude of the average error in percent of the presented altitude. The data on this figure show that the magnitude of the average error and the variation with altitude is about the same as that for the standard deviation, which generally increased with altitude. Even though the actual error was increasing with altitude, its increase was relatively slight, and therefore the error as a percent of the altitude decreased with altitude, rapidly at first from the high values at low altitudes and then more slowly as the altitude increased. In the high altitudes (>60 statute miles (94.9 km)), the error was down to 6 to 8 percent.

The data for the magnitude of the average error shows an anchoring effect at the altitudes for which there is a reseau line (that is, 10, 20, 40, 60, 80) by the fact that the errors at these altitudes are smaller than those for the adjacent altitudes. This difference occurs because the observers tend to read the adjacent altitudes at this same value, and thus the error is increased. This same effect occurred at some halfway altitudes such as 30 and 50 statute miles (48 and 78.8 km) and is a result of the fact that people generally estimate midpoints better than other proportions and the same anchoring effect occurred here.

During the tests it was noticed that some of the observers occasionally made errors so large that they were not compatible with the errors obtained for most of the readings made by that observer. Three of the most probable reasons for this type of error are:

(1) The zero-altitude horizon line on the reseau is not tangent to the displayed horizon. This condition would displace the entire grid high or low.

(2) The displayed horizon curve is not properly centered in the viewer field. This condition would displace the grid sideward so that the subject is susceptible to a wrong reading.

(3) The subject is misreading the altitude of the reseau comparison line.

These errors are errors resulting from improper procedure rather than from inherent errors in the equipment. During the tests, whenever it was recognized that errors of this type were made, the slides were repeated, sometimes several times, to see whether these large errors would recur. In most of the cases, the errors in the repeated readings were more in line with those for the rest of the slides. The data presented so far included all the readings, and in order to evaluate the effect of the divergent readings, the data were screened and all the readings that differed from the best reading by more than 5 miles (8 km) for each subject at each altitude were omitted. The magnitudes of the average error, standard deviation, and error in percent of altitude are presented in figure 6. A comparison of the data in this figure with those in figure 5 shows that there is a reasonable improvement, particularly at the higher altitudes. The general improvement is shown by the comparison of the standard deviations for the basic data and the revised data. The standard deviation σ for the basic data is 4.48 miles (7.2 km) and the standard deviation σ for the revised data is 3.67 miles (5.9 km). This comparison shows that there is about an 18-percent overall improvement due to leaving out the divergent points. The basic standard deviations include all the measured points.

The tests were made with untrained observers, and it is believed that with training, both the accuracy and repeatability could be improved. Some measure of the improvement was indicated by the revised data above. It is felt the results for the revised data should approximate the results achievable with training because the "wilder" readings (spreads greater than 5 which is about the same magnitude as the basic σ (4.48)) were omitted.

Effect of vision correction.- In order to evaluate the effect that vision correction might have on the observers' ability to use the viewer, the observers were chosen so that some did not normally require glasses and some did require correction to their vision. The actual distribution of the 23 observers was as follows: 10 observers who did not normally wear glasses (normal vision), 10 with vision corrected by glasses, and 3 with vision corrected by contact lenses. A comparison of the results obtained for this study is presented in table II.

The data show that in general, the use of corrective lenses did not noticeably affect the results. The only group that showed any appreciable change was the group with contact lenses. This difference was probably a result of the small number of test subjects (3), whose results were near the better end of the data spectrum.

TABLE II.- EFFECT OF CORRECTIVE LENSES ON CORRELATION COEFFICIENT AND STANDARD DEVIATION

	r (1)	σ
Basic data	0.9859	4.48
Normal vision	0.9849	4.63
Corrected vision – glasses	0.9854	4.53
Corrected vision – contacts	0.9911	3.61

[1]The symbol r represents the Pearson product moment correlation coefficient. This coefficient is an indication of how much the variation of the readings with the slides differs from the 1:1 variation (for the 1:1 variation, r = 1.000). (See ref. 6.)

Effect of increased viewing distance.- The screen upon which the scene was projected was only 5 feet (1.5 meters) from the observer; however, the binocular viewer effectively projects the comparison curves from the reseau out to infinity. Therefore, the possibility of an "accommodation problem" existed because of the inability of the observer to maintain both the near and far projections in adequately sharp focus. In order to determine whether increasing the distance between the observer and the screen affected the readings, the projection-viewing system was set up so that the subjects were 11 feet 10 inches (3.6 meters) away from the display and the display was 23 feet 8 inches wide (7.2 meters). It is realized that this distance may not be long enough to obtain a positive answer to the accommodation problem but by utilizing the subjects with the worst readings it was felt that this effect would show up. Five subjects were used for this test. All the subjects had participated in the original tests and the slides were the same. The standard deviation and the correlation coefficient are presented in table III. As can be seen, increasing the viewing distance did not seem to improve the subject's ability to estimate altitude.

TABLE III.- EFFECT OF LONGER VIEWING DISTANCE FOR THE SAME SUBJECTS

	Distance		r	σ
	feet	meters		
Original distance	5	1.5	0.9817	5.22
Increased distance	11'10"	3.6	0.9753	6.00

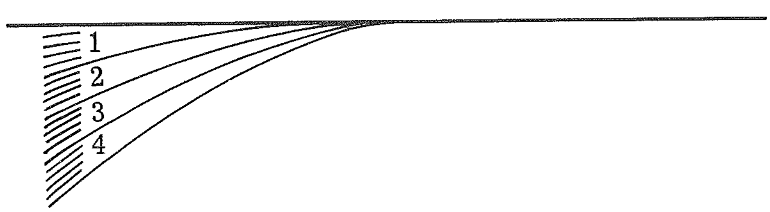
Prediction

The real test of any measuring device is how well it does the job. For the binocular viewer tested and under the conditions of the test, figure 7 answers this question for the group of subjects tested. For a particular reading the figure shows the average altitude which would be expected when that reading was made and also shows the standard deviation about this expected reading. The data for this figure were processed by using two bases for comparison. The initial base assumed that the altitude of the presented slides was correct. These data are presented in figure 7(a). The central line is the predicted altitude and the two flanking lines are the spread of the standard error. The other base assumed that the presented altitude may be in error and that the average reading for each altitude actually was closer to the true altitude. These data are presented in figure 7(b).

The predicted altitude lines are the best-fit straight lines through the data (this curve is a least-squares fit), and both of the lines show a little skewness with respect to the 1:1 correlation. For instance, at low reading altitudes the actual altitude would be slightly higher, and at high reading altitudes, the actual altitudes would be lower. As would be expected, the second base results in a better correlation and smaller deviations than the first base. For example, for a reading of 60 miles (94.9 km), using the presented altitude as a base, the expected altitude would be 58.5 ± 4.2 miles (92.5 ± 6.6 km); however, if the average reading is used as a base, the expected altitude would be 59.7 ± 4.1 miles (96.06 ± 6.4 km). The magnitude of the measured errors had approximately a normal distribution; therefore, based upon this data, the user of this viewer can determine an altitude and have confidence that 95 percent of the time (that is, 2σ) he will be within ±8.5 miles (13.5 km).

General Considerations for Improvement

These results were obtained with untrained observers, and it is believed that with adequate training, the errors could be substantially reduced. A potential improvement to the viewer suggested by several observers was the addition of short tick marks on the reseau between the comparison curves out near their ends as shown in the sketch.



These tick marks would help in the interpolation for intermediate altitudes. In order not to introduce distortions, and to obtain optimum performance from the viewers, it is

necessary to form the front mirror and reseau very carefully. The careful placement and alinement of the lamps used to edgelight the reseau is also necessary to obtain even illumination over the entire reseau so that one portion will not have a more pronounced effect on the observer than another portion.

CONCLUDING REMARKS

An evaluation of a visual-altitude determination device known as the binocular viewer and the ability of a man to use this device to measure altitude has been conducted. Two viewers were tested.

The results using the better of the two viewers showed that for the display used in the tests, the subjects could determine their altitude to within ±5 miles (±8 km). The results were similar for subjects that usually did not wear glasses and those that used corrective lenses.

Several of the subjects were retested at a longer viewing distance to determine whether sight accommodation affected the results. The results of these repeated runs were no better than the results from the original runs, and indicate that there was no appreciable accommodation effect.

The evaluation also showed that the forming of the front spherical bubble of the viewer was very critical. As a consequence, one viewer was considered unusable and the effectiveness of the second was impaired because of the distortion introduced by the front bubble.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., September 15, 1969.

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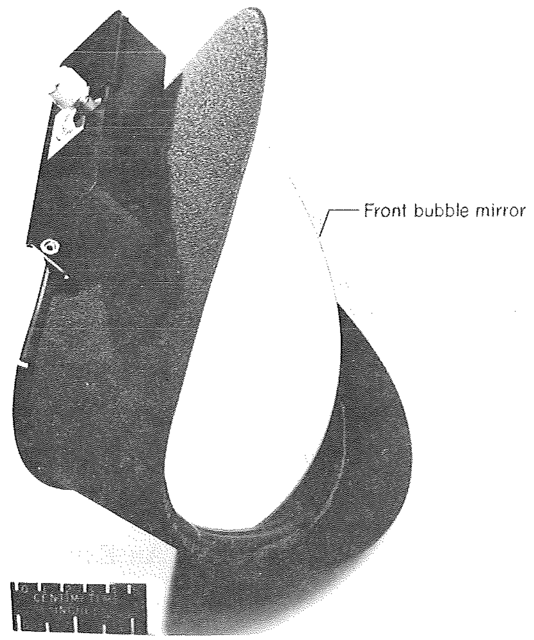
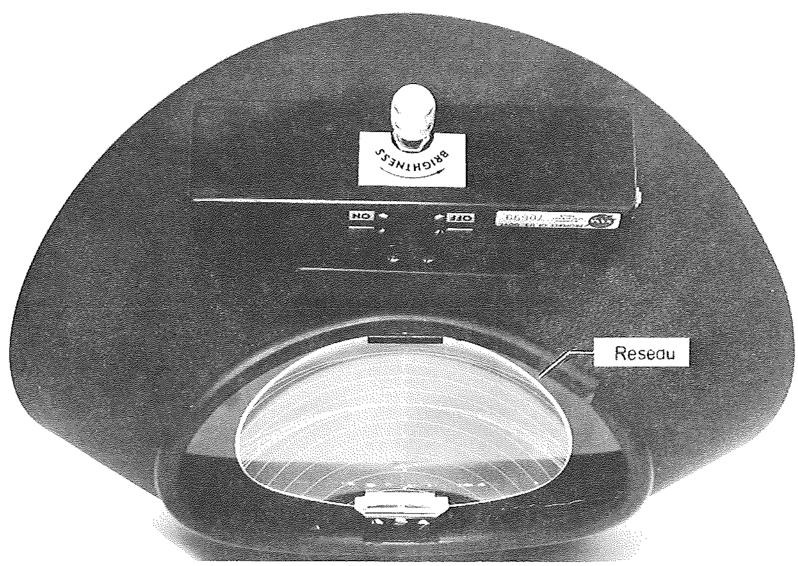


(a) Three-quarter top side view.



(b) Three-quarter top rear view.

Figure 1.- Photographs of binocular viewer.

L-69-5101

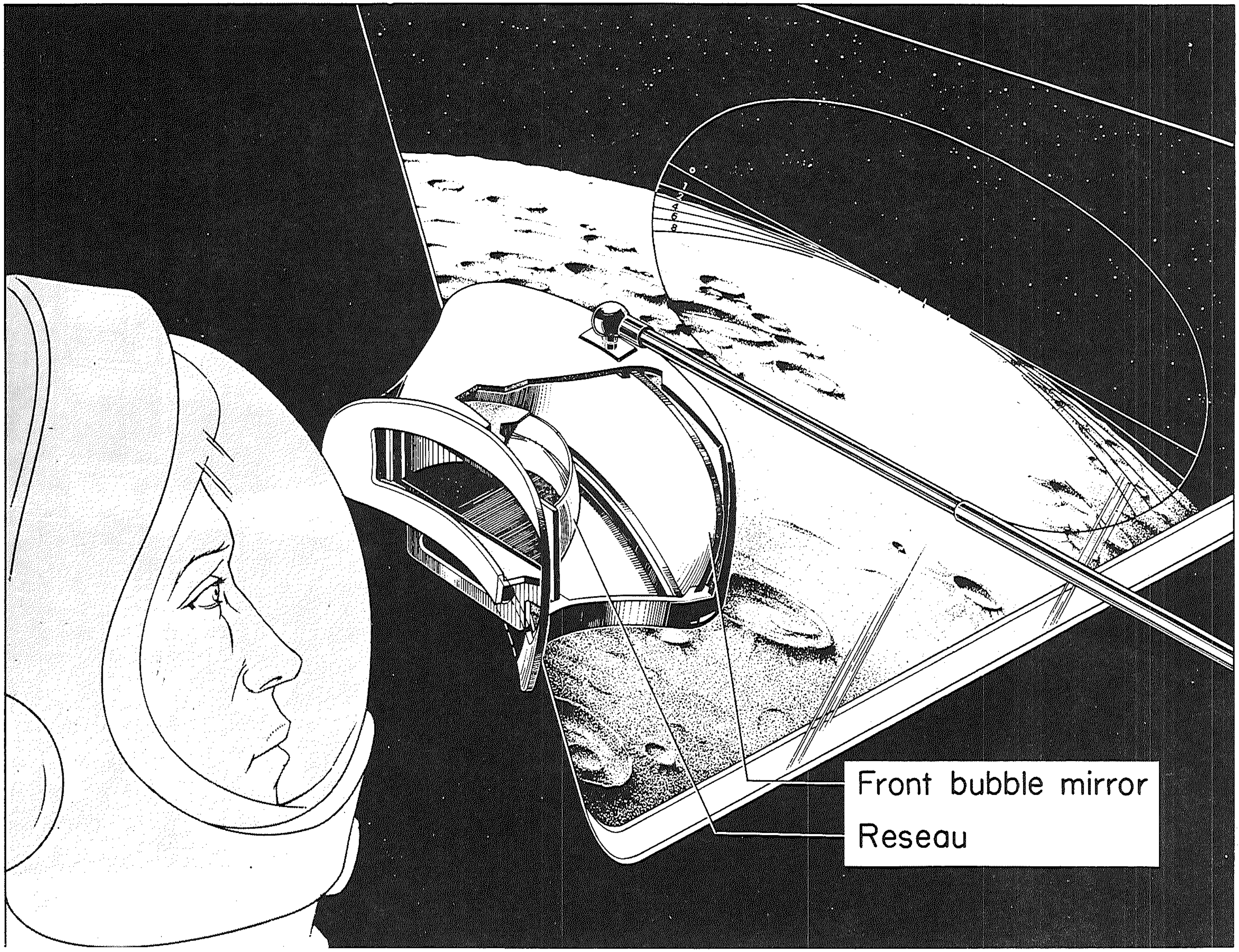


Figure 2.- Pictorial sketch of binocular viewer.

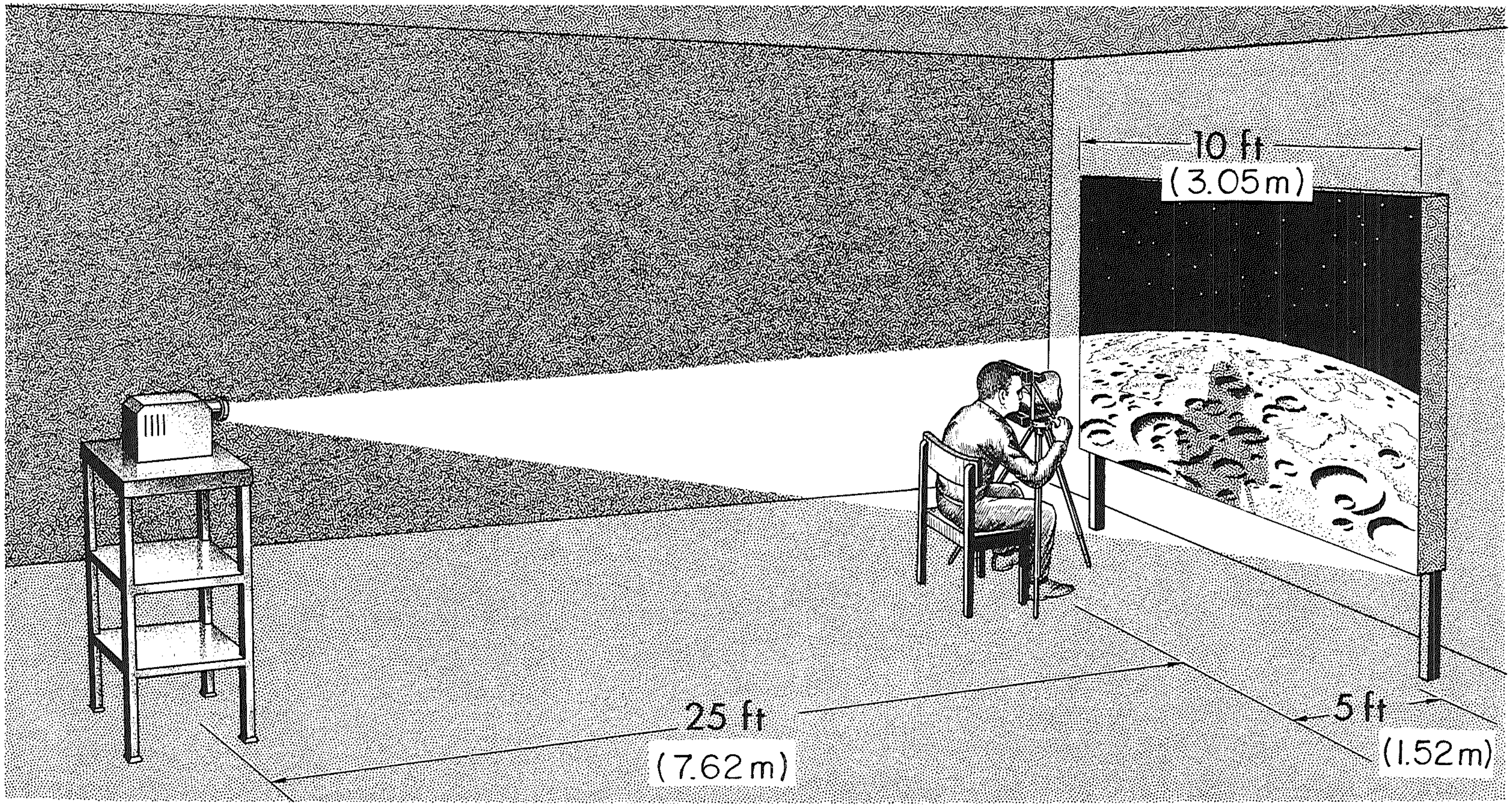


Figure 3.- Pictorial sketch of test setup.

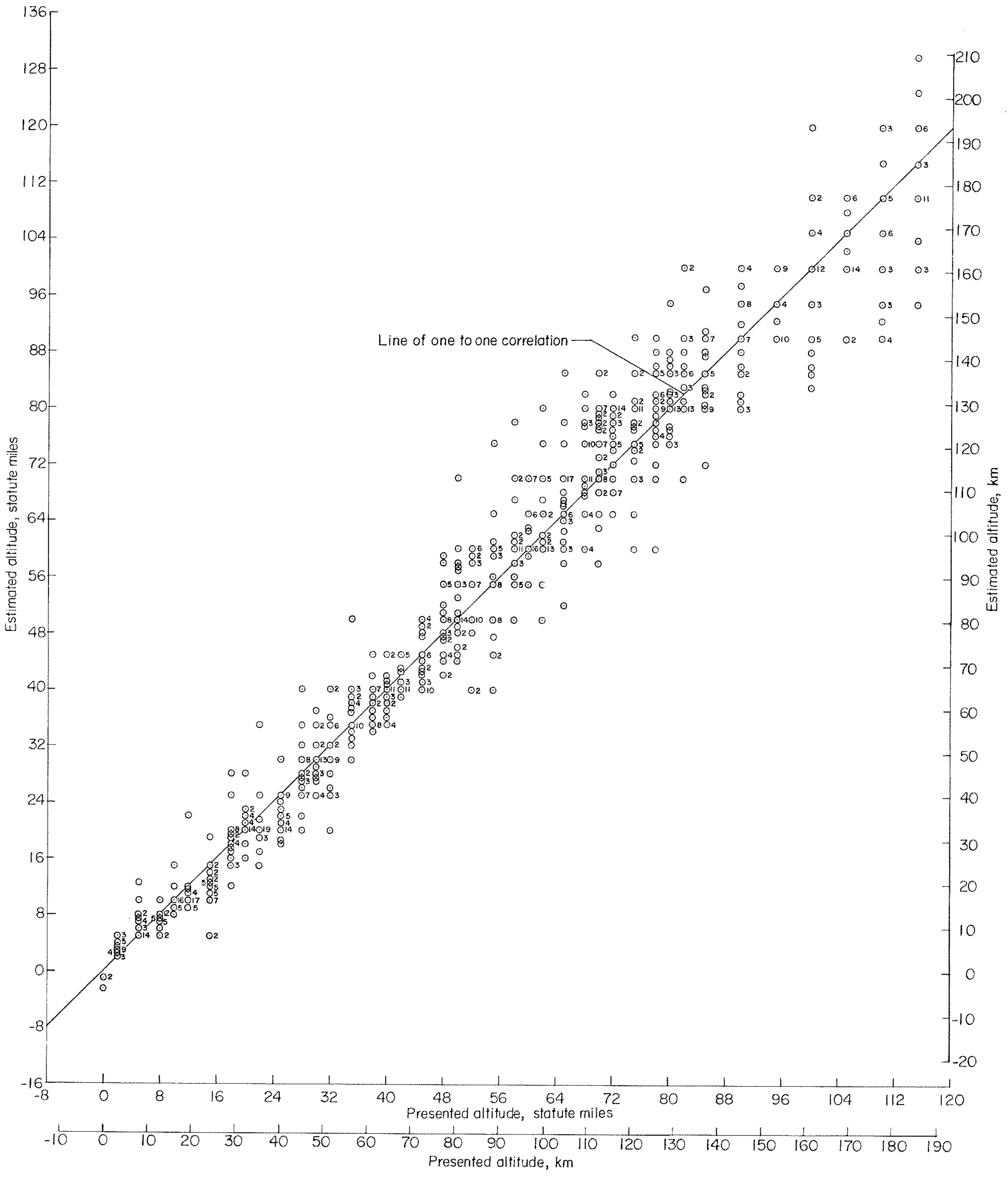


Figure 4.- Compilation of all the data for all observers. Numerals beside the points indicate the number of times that estimate was made.

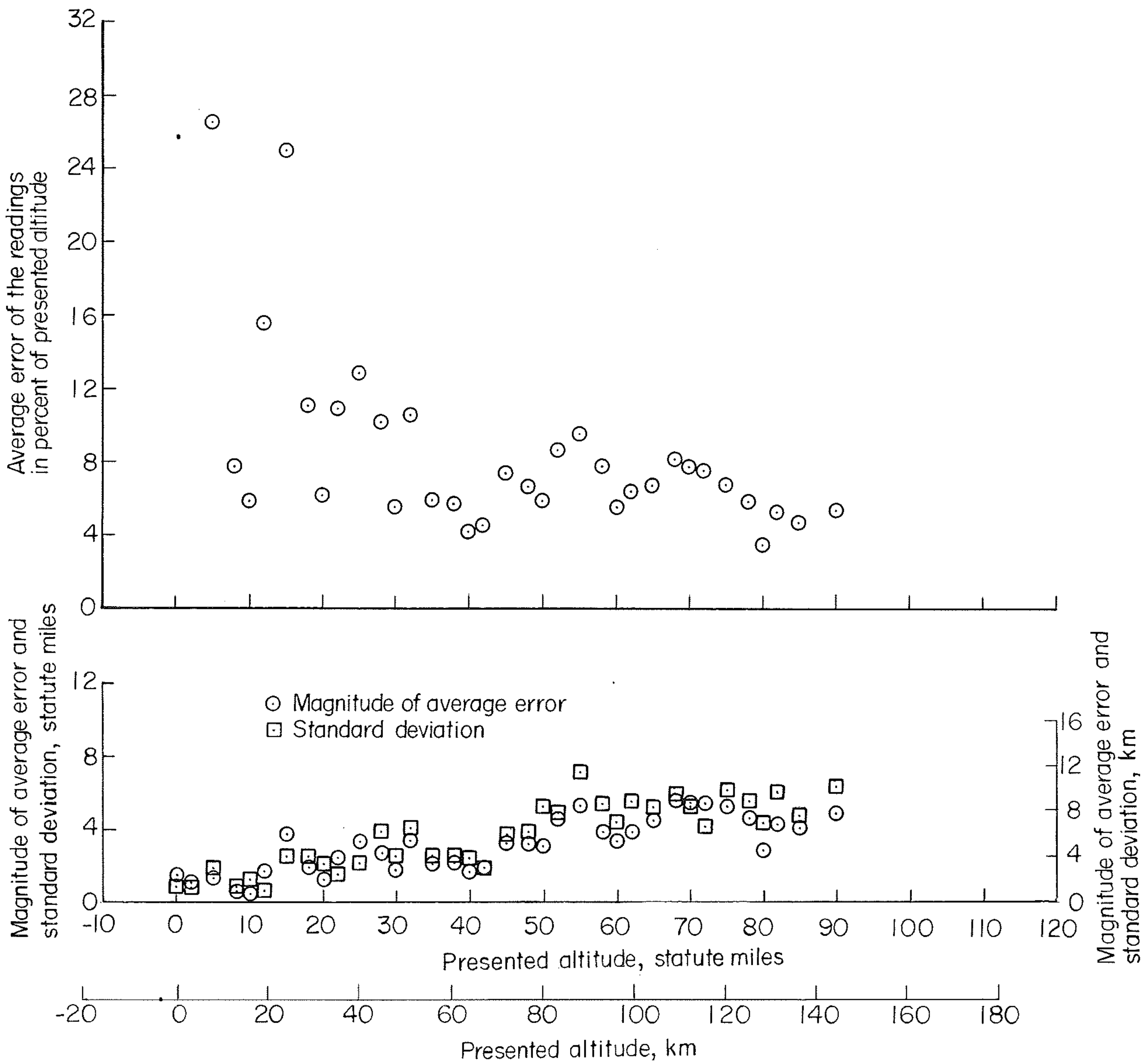


Figure 5.- Magnitude of the average error and standard deviation in miles and the error in percent of the presented altitude for the basic data.

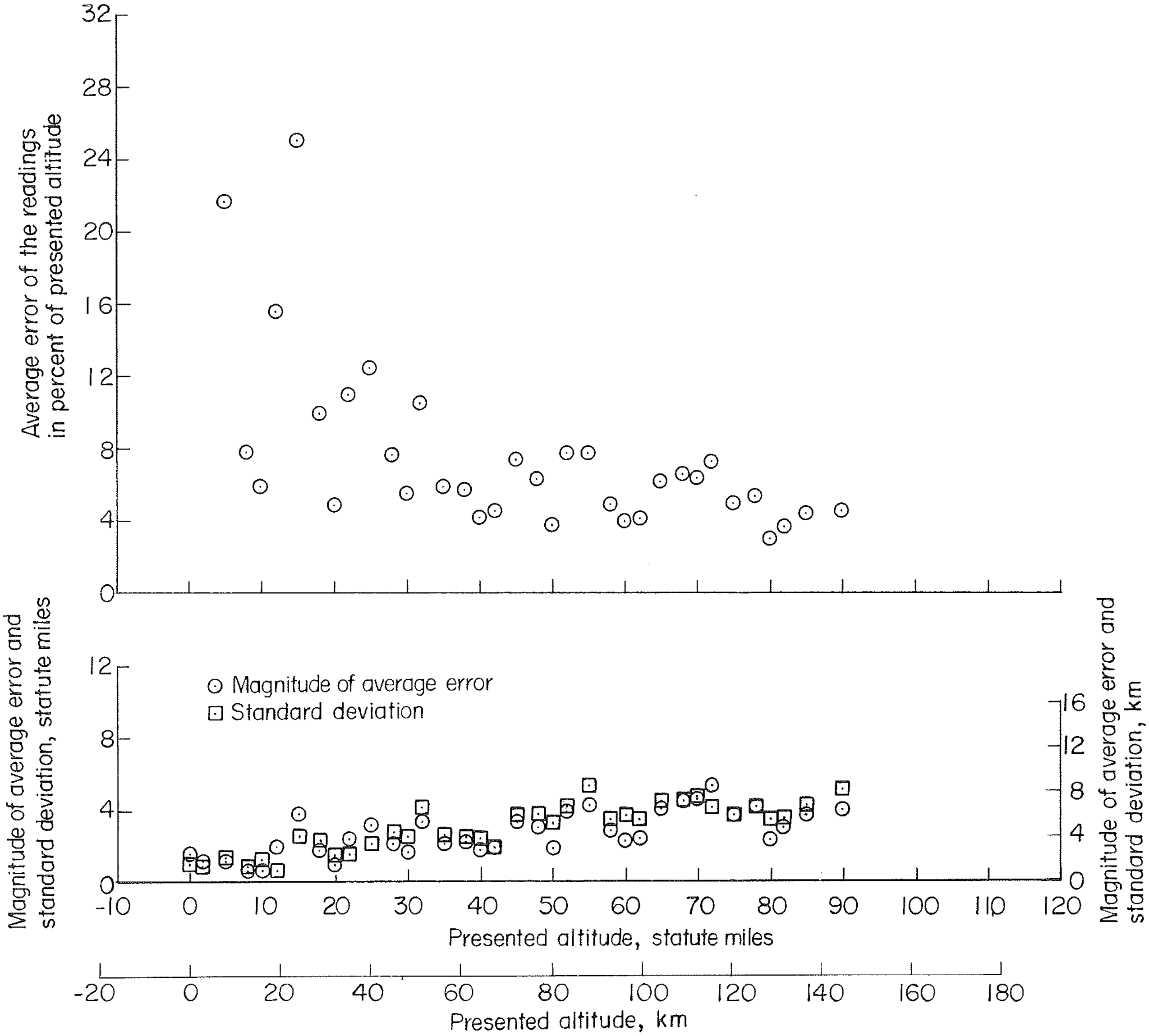
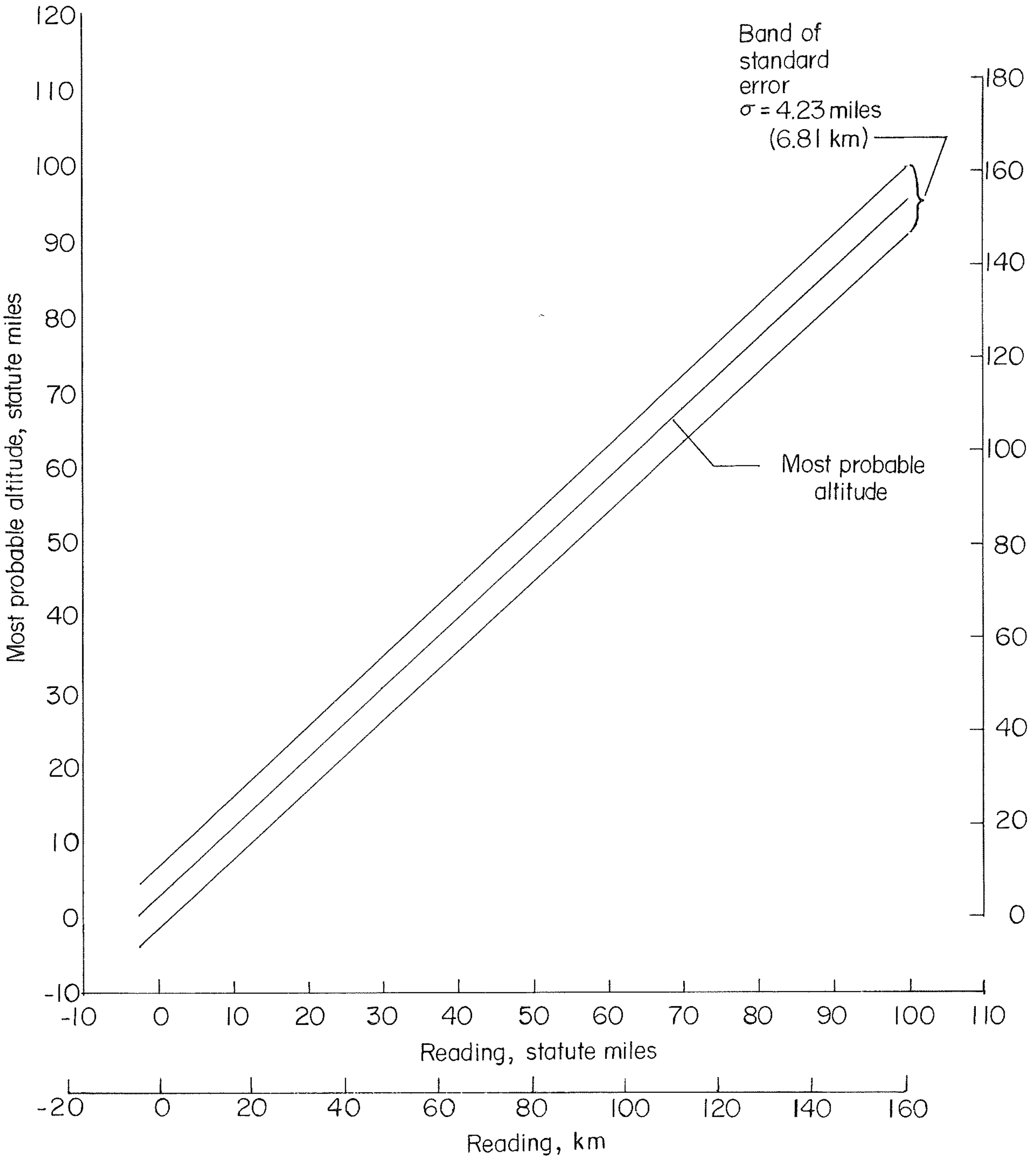
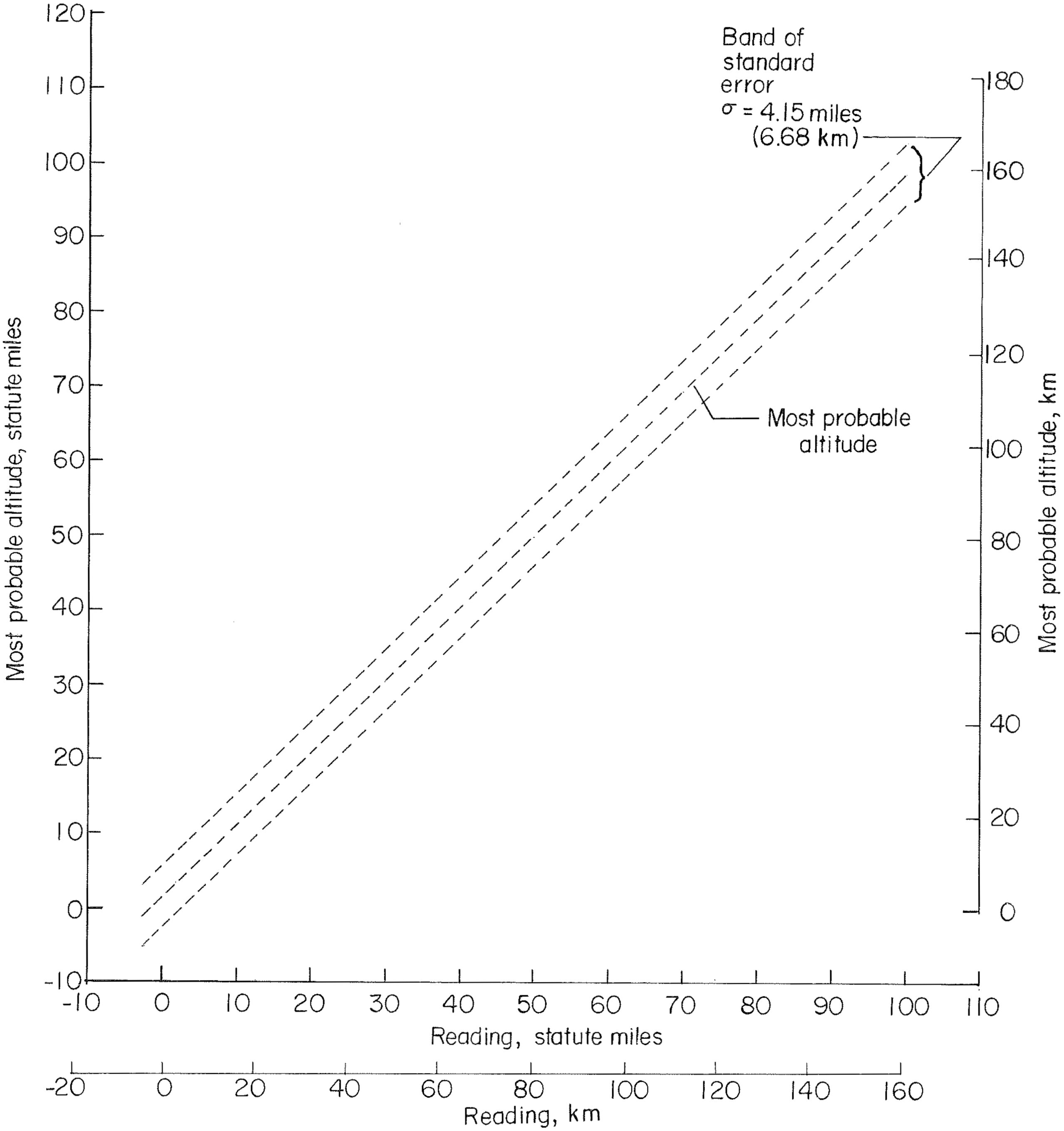


Figure 6.- Magnitude of the average error and standard deviation in miles and the error in percent of the presented altitude for the revised data.



(a) Data based on the assumption that the presented altitudes are correct.

Figure 7.- Relationship showing the variation of the most probable altitude with the observers' readings and the band of standard deviation.



(b) Data based on the assumption that the average reading was the correct altitude.

Figure 7.- Concluded.

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